Theory of Thermal Conduction in Thin Ceramic Films

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The theories of heat conduction by lattice waves and by infrared radiation are applied to thin ceramic films. Conduction normal to the film and in the plane of the film will both be discussed. The temperature range considered here is from room temperature to 1200 ° C. The radiative component of the thermal conductivity depends on film thickness, and is important mainly at high temperatures and for thick films. For both components, one must consider the distribution of heat flow in the frequency spectrum of the waves. Different scattering and interaction processes operate in different frequency ranges.

The mean free path of lattice waves is limited by anharmonic three-phonon interactions, by scattering off-point defects (of atomic dimensions) and by scattering off extended imperfections such as inclusions, pores, splat boundaries, platelets, and grain boundaries. Grain boundaries scatter, not because of the misorientation between neighboring grains, but because of thin layers of modified material between the grains. The attenuation length of e.m. waves is limited by absorption and also by various imperfections. The larger wavelength of the thermal radiation compared to lattice waves implies that the scattering processes important to radiation arise from imperfections of larger size, approaching micron size at least in one direction. Thick splat boundaries, large pores, and inclusions are the important defects for radiation.

Specific examples to be discussed include zirconia-based thermal barrier coatings, silicon carbide and diamond films, and changes in thermal conductivity due to particle irradiation damage in alumina.